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(54) METAL-TO-METAL COUPLING

(71) We, RAYCHEM CORPORATION, a Corporation organised under the laws of the State of California, United States of America, of 300 Constitution Drive, Menlo Park, California 94025, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to couplings which permit the leak-free sealing connection of a hydraulic line to a hydraulic component such as a pump, a compressor or a hydraulic cylinder.

Many hydraulic components are provided with a standard threaded female boss and most couplings utilize an adapter which screws into the threaded boss. It is necessary that a fluid-tight connection be made between the hydraulic component and this adapter and hitherto rubber O-rings have frequently been used for this purpose.

It is also necessary to seal the adapter, which is often a threaded nipple, to the hydraulic line. A common method for connecting a hydraulic line to a nipple extending from a hydraulic component is to utilize flared tubing which is tightened onto the threaded nipple by a nut which fits over the tubing. This nut holds the flared end against the threaded nipple. Another common method is to place an elastic ring around the outside diameter of the tubing near its end. This elastic ring is then caused to press against the outside of the tubing and the nipple by an overlying nut which screws onto the threaded nipple extending from the hydraulic component.

It has long been recognized that a metal seal for hydraulic parts would have many advantages over rubber and plastic seals. A metal-to-metal seal is disclosed in U.S. Patent No. 3,083,989 issued to I.D. Press wherein a metal flange is tightened against a mating surface, an elaborate arrangement being necessary to secure the flange-containing member to the hydraulic tubing. A metal seal is far less affected by temperature and cannot be softened or swollen by hydraulic fluids but unfortunately, seals made from many metals tend to scratch or cause galling of the sealing surfaces of the hydraulic component. To attempt to correct this problem, seals have been made from soft metals but then they lack the physical properties of the harder metals which are necessary to withstand high pressure.

Recently, heat recoverable or "memory" metals have been utilized to form metal-to-metal couplings, one such coupling being disclosed in our Belgian Patent No. 755,271, inventors J. D. Harrison and J. B. Jervis. Especially suitable alloys for such couplings are disclosed in our Belgian Patent No. 769,468, inventors J. D. Harrison, J. Y. Choi and P. R. Marchant.

As disclosed in the aforementioned Belgian Patent 769,468, Belgian Patent 755,271 and Chapter 22 of Intermetallic Compounds edited by J. H. Westbrook, Wiley & Sons 1967, certain alloys can be made to convert from a relatively strong austenitic state to a relatively weak martensitic state by reducing the temperature of the alloy to below its transition temperature. In fact transition generally takes place over a temperature range and all references to transition temperature herein are meant to include this possibility.

Alloys containing major proportions of titanium and nickel exhibit the ability to be transformed reversibly from an austenitic state to a martensitic state by a temperature change. Small amounts of metals such as iron, aluminium or manganese may be incorporated with major amounts of titanium nickel to result in an alloy with the desired transition temperature. By way of example, the following alloys (in atomic percents) have

transition temperatures above −196°C and below −75°C.

Titanium	50	Nickel 47	Iron	3
Titanium	49	Nickel 50	Aluminium	1
Titanium	50	Nickel 48	Manganese	2

The alloy preferably has a transition temperature above −196°C since then it can be converted to a martensitic state by immersing it in readily available liquid nitrogen.

The phase from martensitic to austenitic can also be made to result in heat recoverability, i.e. changes of dimension on being heated through the transition temperature, by the addition of stresses to the alloy especially when it is in its martensitic state. This is also described in the aforementioned Belgian Patent 769,468.

Other heat recoverable metals are disclosed in U.S. Patent Nos. 3,012,882 and 3,174,851 and Belgian Patent No. 703,649 the disclosure of which are incorporated by reference herein.

The present invention is based on our surprising observation that, besides being useful in the manufacture of hydraulic couplings, such metals can advantageously be utilized to form sealing elements for such couplings.

The present invention accordingly provides a metal-to-metal coupling wherein between the parts being coupled there is provided a seal made from a metal which can be converted from a relatively strong austenitic state to a relatively weak martensitic state by reducing its temperature below an appropriate transition temperature.

As indicated previously, the present invention is especially applicable to the making of a coupling between a hydraulic component and an adapter therefor and makes possible a metal seal of great strength but yet one which will not scratch or gall the sealing surface of the hydraulic component during installation. This beneficial combination of properties is permitted by the use of heat-recovery or "memory" metals, preferably alloys of titanium and nickel, which exhibit vastly different physical properties at different temperatures.

Thus, to form a strong galling resistant seal according to the present invention the adapter and metal seal are cooled to below the transition temperature of the seal and the adapter is affixed to the hydraulic component. The seal is then allowed to warm above its transition temperature when it converts from its weak martensitic state to its strong austenitic state. The alloy from which the seal is made should have a transition temperature below the operating temperature of the hydraulic equipment in order to keep the seal in its austenitic state during operation.

The heat recoverability or "memory" properties of the metal may also be utilized to cause a change in shape of the seal as it is warmed above its transition temperature. Thus the seal, in its martensitic state, may be deformed so as to fit over an enlarged area on the adapter and when warmed to its austenitic state will revert to its original configuration and become captive. Additionally, the seal may become captive by engagement along its outer surface.

In an especially preferred embodiment of the present invention, there is provided a coupling between a hydraulic component and hydraulic tubing, comprising:

an adapter capable of being attached to said hydraulic component at its first end and having a sealing means at its other end;

means for attaching said adapter to said component;

a seal adapted to fit between said component and said adapter, said seal being made from a metal which can be converted from a relatively strong austenitic state to a relatively weak martensitic state by reducing its temperature below the appropriate transition temperature;

a sleeve attached to said hydraulic tubing, said sleeve having a sealing surface adapted to mate with the sealing suface of said adapter; and

means for holding said sleeve against said adapter to effect sealing between said sealing surfaces.

The second sealing point in this embodiment of the present invention exists between the adapter and the hydraulic line. This second seal preferably also utilizes a heat recoverable metal but for a different reason. A heat recoverable sleeve is first affixed to the hydraulic line; this may be done by several methods including shrinking the sleeve over the hydraulic line in a manner described in the afore-mentioned Belgian Patent No. 755,271. This sleeve is provided with a generally circular mating surface corresponding to a mating surface on the adapter and means are provided to tighten and hold the sleeve against the adapter, said means for holding the sleeve against the adapter preferably comprises an enlarged end portion on the sleeve and a coupling nut fitting over the body of the sleeve, the nut having a threaded portion extending beyond the enlarged end portion of the sleeve and engaging a correspondingly threaded portion on the adapter.

Either one or both of the mating sealing surfaces is preferably undercut to permit some movement of this mating surface along the direction of the axis of the coupling, for example, one of the mating surfaces preferably projects inwardly towards the central longitudinal axis of the coupling so as to permit a small amount of movement of this mating surface in the direction of this axis. Preferably the mating surface of the adapter comprises a circular surface located near the

inner diameter of the adapter and extending radially inward from the maximum inside diameter of the adapter.

Advantageously the mating surface of the adapter is provided with an outer circular projecting ring, the mating surface of the sleeve being provided with a correspondingly circular recessed portion. Furthermore the mating surface of the sleeve is preferably itself provided with a circular projecting ring of smaller diameter than its recessed portion, the mating surface of the adapter being provided with a recessed portion corresponding to this projecting ring on the sleeve.

Preferably the metal seal is formed as a V-ring and has at least one substantially semi-circular sealing surface formed, for example, by a terminal beaded portion on one arm of the V. Advantageously the V-ring is symmetrical.

The resulting coupling is a removable all-metal coupling useful over a wide temperature range and unaffected by solvating properties of the hydraulic fluid. Also, the hydraulic component is not scratched by the installation of the adapter and yet a seal of great strength results.

The present invention will now be described in more detail, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a plan view partly in section of a coupling of the present invention;

Figure 2 is an enlarged framentary view of the seal end portion of Figure 1 shown prior to final engagement;

Figure 3 is an enlarged fragmentary view of the seal end portion of Figure 1 shown after final engagement;

Figure 4 is an enlarged fragmentary view of the sleeve end portion of Figure 1 shown prior to final engagement;

Figure 5 is an enlarged fragmentary view of the sleeve end portion of Figure 1 shown after final engagement;

Figure 6 is an enlarged cross sectional view of a second form of seal end portion prior to heat recovery; and

Figure 7 is an enlarged cross sectional view of the end portion of Figure 6 after heat recovery.

Referring to the drawings, especially Figure 1, a threaded hole or boss is provided in hydraulic component 1 which is provided with a mating surface 2 at the outer edge of the hole. An adapter 3 is shown screwed into the boss in hydraulic component 1. A V-ring seal 4 fabricated from one of the alloys hereinbefore described is shown in a recess of adapter 3 and mates both with the adapter and mating surface 2 thereby preventing fluid leakage between the hydraulic component and the adapter. The adapter is threaded at one end to fit the threaded hole in the hydraulic component. The outside diameter of the adapter is also threaded at its other end to permit the attachment of coupling nut 5 thereon. The adapter 3 has an intermediate hexagonal wrench flat which facilitates tightening of the adapter into the threaded hole. The recess is located beneath this wrench flat. Adapter 3 has an outer circular projecting ring 6 which serves to protect circular mating surface 7. Recessed area 8 has been formed behind circular mating surface 7 to permit some movement of the mating surface as described below. This movement provides an initial sealing pressure.

Sleeve 10 fabricated from one of the alloys hereinbefore described has been securely shrunk about hydraulic line 11 by the manner described in Belgian Patent No. 755,271. Sleeve 10 has a projecting ring 12 which provides scuff protection for the circular mating surface 13 on the sleeve and also helps to align the adapter with the sleeve prior to tightening. The sleeve 10 also has a recessed portion 14 which provides a stop for outer circular projecting ring 6 of the adapter. The shoulder 15 of coupling nut 5 pushes against the shoulder 16 of the sleeve 10 to cause the sleeve to be brought against the adapter 3 when the coupling nut is screwed on the adapter. The operation of the seal between mating surfaces 7 and 13 is more clearly shown in Figures 4 and 5 where adapter 3 and sleeve 10 are shown prior to tightening in Figure 4 and after tightening in Figure 5. The circular mating surface 7 of the adapter contacts mating surface 13 of the sleeve before outer circular projecting ring 6 of the adapter has touched the recessed portion 14 of the sleeve 10. As the sleeve 10 is forced toward adapter 3 by coupling nut 5, the mating surface 7 of the adapter moves toward the hydraulic component in a direction generally parallel to the axis of the coupling. This results from the provision of recessed area 8 which forms an inwardly extending arm 9 between the circular mating surface 7 and the main body of the adapter. The result is an action like a belleville spring which maintains a steady force between mating surfaces 7 and 13 thereby forming an excellent seal. The pressure of the hydraulic fluid on the recessed area 8 supplements this force and forms a dynamic seal between these mating surfaces.

Turning now to Figures 2 and 3, the V-ring seal 4 is shown in enlarged cross section in a recessed portion of adapter 3. In Figure 2, the seal is shown prior to tightening in its relatively soft martensitic state and in Figure 3 after tightening and warming up to its relatively strong austenitic state. A bead 20 having a generally semi-circular outer surface is provided at the end of one side of the V-ring which contacts mating surfaces 2 of the hydraulic component. An arcuate surface 21 is provided at the end of the outer side

of heat recoverable seal 4 which contacts adapter 3. The shape of seal 4 is such that hydraulic pressure within the coupling tends to expand the seal against the hydraulic component and the adapter at points 20 and 21. If desired a bead or arcuate surface may be provided on each of the sides of the sealing ring thus preventing any accidental reverse positioning of the ring.

Turning now to Figures 6 and 7, there is shown an alternative configuration of the seal.

In Figure 7, a seal 25 fabricated from one of the alloys hereinbefore described is shown in its sealing position having mating areas at 26 and 27. The hydraulic pressure tends to increase the sealing at these areas. Since, in this configuration, the seal has a mating area 27 on an outer surface of the adapter 3 it is less dependent upon the position of the tightening surface which is shown in Figures 6 and 7 as tightening nut 28. Thus a fluid tight seal results even though the tightening surface is not threaded fully against the hydraulic component.

The seal 25 is shown in Figure 6 in its martensitic state having been deformed which enables it to be placed over the threads of the adapter 3. When the seal is warmed above its transition temperature, it reverts to its stronger austenitic state and to its original undeformed configuration as shown in Figure 7. This has the further advantage of capturing the seal. In order to hold tightening nut 28 in place, a lock nut 29 is also threaded over adapter 3.

The heat recoverable alloy chosen for the seal should have a transition temperature such that its exists in its strong austenitic state at the operating temperatures of the hydraulic system in which it is used. This seal should also be capable of being cooled to below its transition temperature for installation of the adapter into the hydraulic component. In this way, damage to the mating surface of the boss can be minimized. As described in aforementioned Belgian Patent No. 755,271 this may be a very low temperature in that the adapter may be cooled in a fluid such as liquid nitrogen just prior to connection with the hydraulic component.

The sleeve is normally connected to the adapter after the adapter has been connected to the hydraulic component. The means for holding the sleeve against the adapter need not utilize a coupling nut but instead could use a circumferential clamp, a threaded union, or the like. The projecting ring on the adapter and that on the sleeve are not essential to the operation of the coupling but are advantageous to prevent the mating surfaces from becoming marred or scuffed. While the recessed area and inwardly extending arm are shown in the drawings as a portion of the adapter, it could equally well be provided in the heat recoverable sleeve. It is only necessary that a belleville spring type of action exist between the mating surface of the adapter and that of the sleeve.

It is not necessary that the sleeve 10 be fabricated from the same alloy as the seal 4. Its transition temperature, however, should be such that it also exists in its stronger austenitic state at the temperatures at which it will operate.

The particular curvature of the seal shown in the drawing may be varied to a more U shape or a more V shaped configuration as long as the fluid pressure will tend to expand the seal against its two mating surfaces. The hydraulic component need not be a piece of equipment having a threaded hole but could be a second section of hydraulic tubing the coupling thus constituing a union between hydraulic lines.

WHAT WE CLAIM IS:—

1. A metal-to-metal coupling wherein between the parts being coupled there is provided a seal made from a metal which can be converted from a relatively strong austenitic state to a relatively weak martensitic state by reducing its temperature below an appropriate transition temperature.

2. A metal-to-metal coupling as claimed in claim 1, wherein the seal has been made heat recoverable prior to coupling the parts and has subsequently changed shape to its coupled configuration.

3. A metal-to-metal coupling as claimed in claim 1 or claim 2, wherein the seal is made from an alloy containing major proportions of titanium and nickel.

4. A metal-to-metal coupling as claimed in claim 3, wherein the alloy further contains a minor proportion of iron, aluminium, manganese or any two or all three said metals.

5. A metal-to-metal coupling as claimed in any one of claims 1 to 4, wherein the transition temperature lies above —196°C.

6. A metal-to-metal coupling as claimed in any one of claims 1 to 5, wherein the seal is a V-ring seal and has at least one substantially semi-circular sealing surface.

7. A metal-to-metal coupling as claimed in claim 6, wherein the sealing surface is a terminal beaded portion on one arm of the V.

8. A metal-to-metal coupling as claimed in any one of claims 1 to 7, which is between a hydraulic component and an adapter therefor.

9. A coupling between a hydraulic component and hydraulic tubing, comprising:

an adapter capable of being attached to said hydraulic component at its first end and having a sealing surface on its other end;

means for attaching said adapter to said component;

a seal adapted to fit between said component and said adapter, said seal being made from a metal which can be converted from a relatively strong austenitic state to a relatively weak martensitic state by reducing its temperature below the appropriate transition temperature;

a sleeve attached to said hydraulic tubing, said sleeve having a sealing surface adapted to mate with the sealing surface of said adapter; and

means for holding said sleeve against said adapter to effect sealing between said sealing surfaces.

10. A coupling as claimed in claim 9, wherein the sleeve is made from a metal which can be converted from a relatively strong austenitic state to a relatively weak martensitic state by reducing its temperature below an appropriate transition temperature.

11. A coupling as claimed in claimed 10, wherein the sleeve is heat recoverable and has been shrunk to grip and hold the hydraulic tubing.

12. A coupling as claimed in any one of claims 9 to 11, wherein the seal is as specified in any one of claims 2 to 7.

13. A coupling as claimed in any one of claims 10 to 12, wherein the sleeve is made from an alloy containing major proportions of titanium and nickel.

14. A coupling as claimed in claim 13, wherein the alloy further contains a minor proportion of iron, aluminium, manganese or any two or all three said metals.

15. A coupling as claimed in any one of claims 9 to 14, wherein the means for attaching the adapter to the hydraulic component comprises a threaded hole in the component and a correspondingly threaded nipple on the adapter.

16. A coupling as claimed in ony one of claims 9 to 15, wherein the means for holding the sleeve against the adapter comprises an enlarged end portion on the sleeve and a coupling nut fitting over the body of the sleeve, the nut having a threaded portion extending beyond the enlarged end portion of the sleeve and engaging a correspondingly threaded portion on the adapter.

17. A coupling as claimed in any one of claims 9 to 16, wherein one of the mating sealing surfaces is undercut to permit movement of this mating surface along the direction of the axis of the coupling.

18. A coupling as claimed in claim 17, wherein one of the mating surfaces projects inwardly towards the central longitudinal axis of the coupling.

19. A coupling as claimed in claim 18, wherein the mating surface of the adapter comprises a circular surface located near the inner diameter of the adapter and extending radially inward from the maximum inside diameter of the adapter.

20. A coupling as claimed in any one of claims 9 to 19, wherein the mating surface of the adapter is provided with an outer circular projecting ring, the mating surface of the sleeve being provided with a correspondingly circular recessed portion.

21. A coupling as claimed in claim 20, wherein the mating surface of the sleeve is itself provided with a circular projecting ring of smaller diameter than its recessed portion, the mating surface of the adapter being provided with a recessed portion corresponding to this projecting ring on the sleeve.

22. A method of making a metal-to-metal coupling which comprises:

making a seal from a metal which can be converted from a relatively strong austenitic state to a relatively weak martensitic state by reducing its temperature below an appropriate temperature, said transition temperature lying below the intended operational temperature of the coupling.

cooling the seal below said transition temperature,

placing the seal between the parts to be coupled,

coupling said parts, and

warming the coupling to a temperature greater than said transition temperature.

23. A method as claimed in claim 22, wherein the seal is also made heat recoverable prior to coupling said parts so that on warming it converts to its final configuration in the austenitic state.

24. A method as claimed in claim 22, wherein the coupling is as specified in any one of claims 2 to 21.

25. A metal-to-metal coupling, whenever made by a method as claimed in any one of claims 22 to 24.

26. A metal-to-metal coupling as claimed in claim 1 substantially as described herein with reference to, and as illustrated in, the accompanying drawings.

27. A coupling as claimed in claim 9, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.

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1299819 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

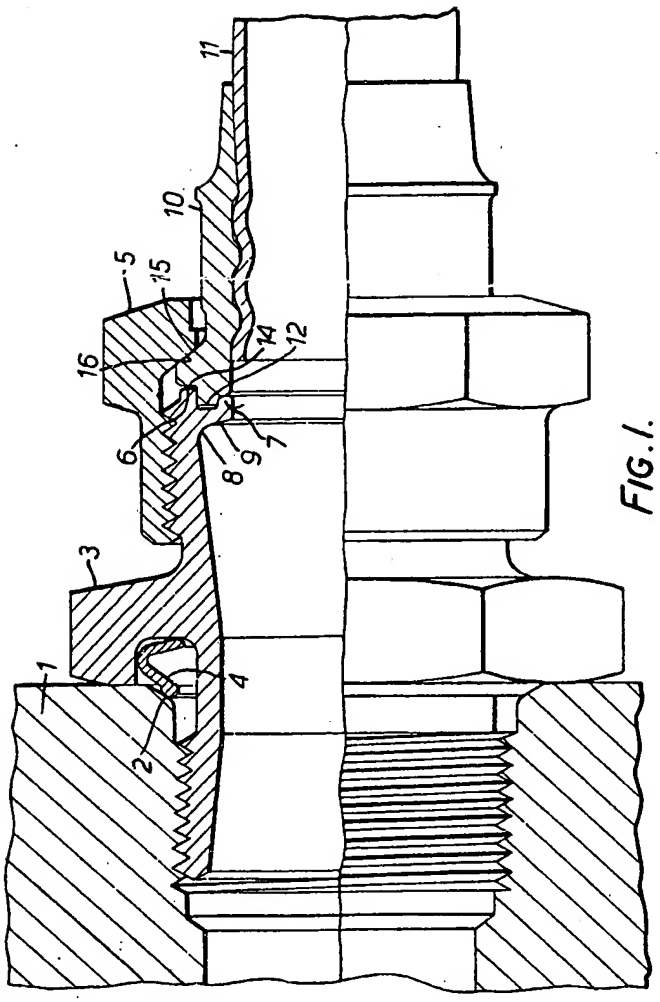

FIG. 1.

1299819 COMPLETE SPECIFICATION

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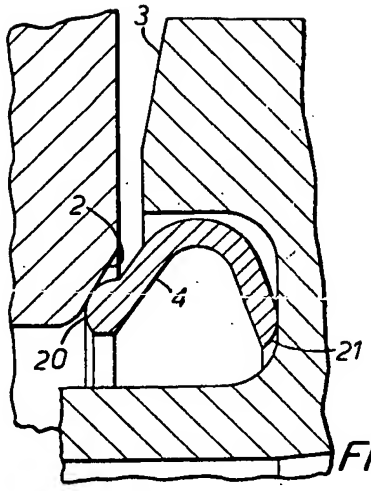

FIG. 2.

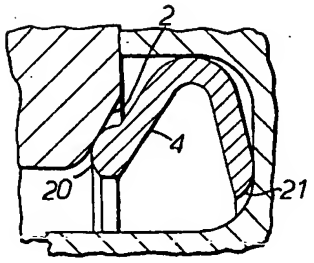

FIG. 3.

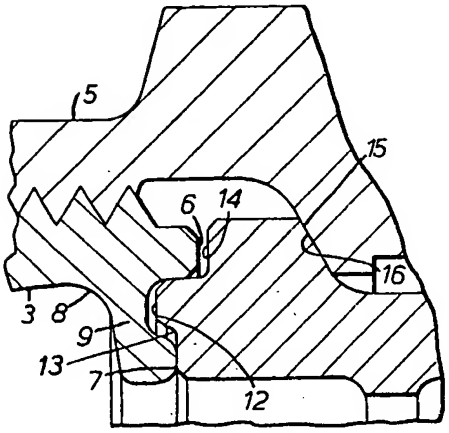

FIG. 4.

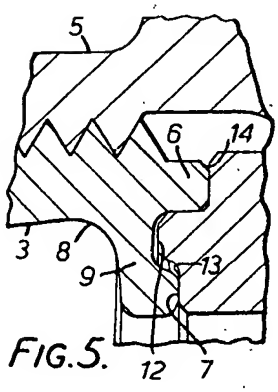

FIG. 5.

1299819 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

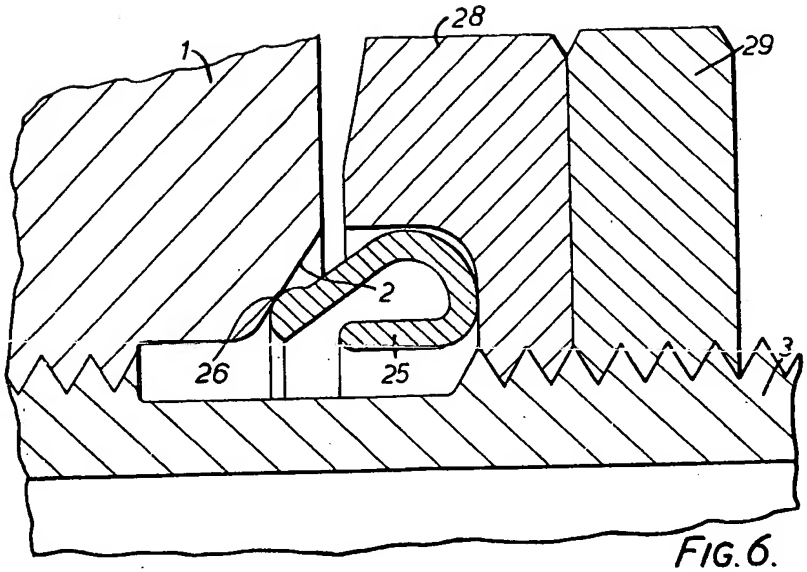

FIG. 6.

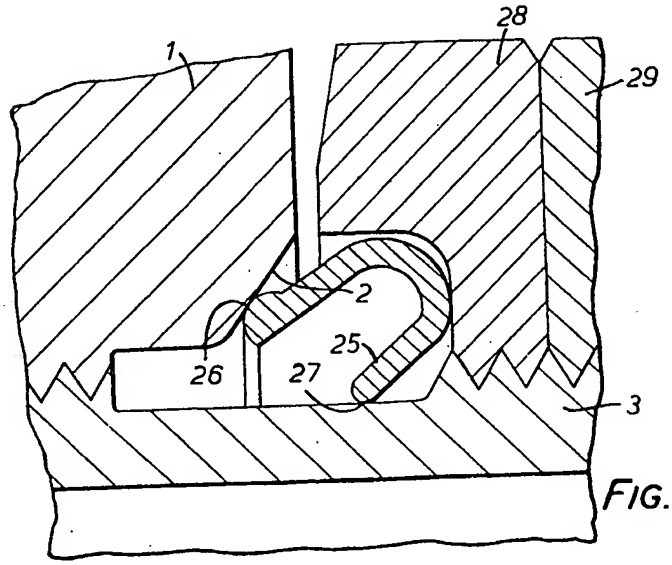

FIG. 7.